The Egyptian Journal of Medical Human Genetics (2012) 13, 37–43

Ain Shams University

The Egyptian Journal of Medical Human Genetics

www.ejmhg.eg.net
www.sciencedirect.com

ORIGINAL ARTICLE

Role of treadmill training versus suspension therapy on balance in children with Down syndrome

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Received 24 August 2011; accepted 26 October 2011
Available online 29 November 2011

KEYWORDS
Down syndrome;
Balance;
Treadmill;
Suspension therapy

Abstract *Background and purpose:* Maintaining balance is a subordinate but necessary requirement for most human actions. Most Down syndrome (DS) children, who constitute a large portion in our country, continue to evidence deficits in balance, co-ordination, and gait throughout childhood and adulthood. So, it is essential to seek an ideal physical therapy program to help in solving such a widespread problem. The present study was conducted to compare between the effect of treadmill training and suspension therapy on balance in children with DS.
Subjects and methods: Thirty children born with DS from both sexes ranging in age from eight to ten years old were assigned into two groups of equal number. Study group I received treadmill training in addition to a designed exercises therapy program and study group II received suspension therapy in addition to the same exercises program given to the study group I. Stability indices were evaluated via using Biodex instrument system before and after three months of treatment.
Results: The results revealed no significant difference when comparing the pre-treatment mean values of the two groups (study I and study II), while significant improvement was observed in all the

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Peer review under responsibility of Ain Shams University.
doi:10.1016/j.ejmhg.2011.10.001

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measuring variables of the two groups when comparing their pre and post treatment mean values. Significant difference was also observed when comparing the post treatment results of the two groups in favor of the study group II.

Conclusion: Suspension therapy for children with DS is an excellent supplement to regularly scheduled physical therapy intervention for the purpose of improving the degree of stability in those patients.

1. Introduction

Down syndrome (DS) is one of the few disabilities that carry with it the certainty of delays in all of the developmental domains [1]. Children with DS perform poorly in measures of running speed, balance, visual motor control, strength and overall gross and fine motor skills in comparison with normal children of corresponding age [2].

Balance control is important for competence in the performance of most functional skills, helping children to recover from unexpected balance disturbances, either due to slips and trips or to self-induced instability when making a movement that brings them toward the edge of their limits of stability [3]. Difficulties in determining individual causes of balance impairment and disability are related to the diverse mechanisms involved. Decreased muscle strength, range of movement, motor coordination, sensory organization, cognition, multisensory integration and abnormal muscle tone contribute to balance disturbances at different levels [4].

Treadmill training was used for children with DS which helps them to improve balance and build strength of the lower limbs so they could walk earlier and more efficiently than children who did not receive any treadmill programs [5].

The treadmill stimulates repetitive and rhythmic stepping while the patient is supported in an upright position and bearing weight on the lower limbs [5]. A positive correlation exists between balance impairments and decreased lower-limb strength. In addition, poor trunk control negatively influences overall balance [4].

Suspension therapy is an innovative and effective modality for treatment. It can be combined with conventional physical therapy methods and can be successfully combined with most of rehabilitation and sport equipment to give postural stability while promoting independence with security which significantly improves balance and coordination of the body and the performance of the vestibule system, also, it allows more full use of the patient's strength and abilities [6].

Biodex stability system is an important balance assessment and training system. In addition, it is the unique device which is designed to stimulate joint mechanoreceptors and assess neuromuscular control by quantifying the ability to maintain dynamic postural stability. This system also acts as a valuable training device to enhance the kinesthetic ability [7].

A clinical trial was conducted to compare between the effects of treadmill training and suspension therapy via using spider cage in DS children who were unable to maintain balance.

2. Patients and methods

2.1. Patients

Thirty children with DS from both sexes between the ages of 8 and 10 years ($x' = 9.34 \pm 0.62$ years) participated in the study which was held in the out-patient clinic of The Faculty of Physical Therapy, Cairo University. Their height ranged between 110 and 125 cm ($x' = 118 \pm 0.09$ cm). They had sufficient cognition and were able to understand commands given to them. They were able to stand and walk independently with frequent falling.

Patients who had balance problems were included in this study as confirmed by the tilt board balance test which was performed under two conditions, tilting board with eyes opened and tilting board with eyes closed. The children were considered to have balance problems when the average sum of the maximum degrees of tilt in four directions (anterior–posterior and medial –lateral) done with both, eyes opened and eyes closed were less than 32.1° and 25.8°, respectively [8].

Children with any medical condition that would severely limit their participation in the study as vision or hearing loss, cardiac anomalies or musculoskeletal disorder were excluded. Neither race nor sex precluded children from being enrolled in the study.

Subjects were classified randomly into two groups of equal number study group I received treadmill training and study group II received suspension therapy via using spider cage. In addition the two groups received exercises therapy program to facilitate postural control and balance.

2.2. Methods

All procedures were explained to the parents and participants, each of them signed a consent form prior to participation. Participants received the treatment program in the out-patient clinic three times/week for three months successively. Test sessions lasted approximately 15 min and practice sessions lasted one hour.

Each group received exercises program for balance and posture control for 30 min in addition to 30 min treadmill training for study group I and 30 min suspension therapy for study group II.

2.2.1. Test session

Biodex stability system was used to assess balance and postural stability. Each child in the two groups was asked to stand on the center of locked platform within the device with two legs stance while grasping the handrails, the display screen was adjusted so that each participant can look straight at it. At first, certain parameters were fed to the device.

(1) Child's weight, height and age.
(2) Stability level (platform firmness).

Each participant was then asked to achieve a centered position in a slightly unstable platform by shifting his/her feet position until it was easy to keep the cursor (representing the center of the platform) centered on the screen grid while standing in comfortable upright position. Once the participant was centered, the cursor was in the center of the display target, he/she was asked to maintain his/her feet position till the platform was stabilized. Heels coordinates and feet angles from the platform were recorded as follows: heels coordinates were measured from the center of the back of the heel, and foot angle was determined by finding a parallel line on the platform to the center line of the foot.

The test began after introducing feet angles and heels coordinates into the Biodex system. The platform advanced to an unstable state, then the child was instructed to focus on the visual feedback screen directly in front of him with both arms at the side of the body without grasping handrails and attempting to maintain the cursor in the middle of the bullseye on the screen. Duration of the test was 30 s for each participant and the mean of three repetitions was determined.

A print out was obtained at the end of each test including overall stability index, antero-posterior stability index, and medio-lateral stability index. The high values mean that the child had balance difficulty.

This test procedure was carried out for each child in the two groups before and after three months of treatment programs.

NB: A familiarity session occurred prior to the test session. This session was particularly necessary for participants with DS to ensure their comfort with the research team and protocol. In this session, participants practiced walking over treadmill and exercises within spider cage. Also, an explanatory session on the Biodex instrument system was conducted to be aware of the different test steps.

2.2.2. Practice session

For the study group I: As it is difficult for children with DS to reliably report their comfortable walking speed on a treadmill, therefore based on our pilot work and the work of others and the fact that comfortable speeds on a treadmill are slower than over ground walking [9], a comfortable treadmill speed was selected for all participants as 75% of their comfortable speed during over-ground walking [10].

Our pilot work demonstrated that self-selected speeds were stable across multiple visits to the out-patient clinic.

Participants proceeded to walk multiple times back and forth across the room as a warming up for approximately 5 min.

The practice on the treadmill (En Tred) was done at 75% of over-ground speed and zero degree inclination for 20 min, three times/week for 3 months, successively [11].

Children were kept upright with their feet flat on the treadmill belt and the height of the handrails adjusted to suit every child. It was important to try to keep the child looking forward as much as possible to stimulate the conditions of independent walking.

In the protocol of treadmill training, each minute was classified into 15 s. with both hands on the treadmill handrail, 15 s. with one hand on the handrail, and 30 s without holding onto the treadmill bar, this maneuver was repeated twenty times [10]. Cooling down for 5 min was done after the end of the procedures.

The children practiced while wearing street clothes, and with sport shoes. For all children, conversation about their interests was done in addition to verbal and visual encouragement to motivate them.

For the study group II: The children received a designed physical therapy program inside the "spider cage". Each child was placed in standing position in the center of the cage. He/she hooked up in the spider cage by a means of belt around his/her waist that attached to the cage using elastic cords. The belt was fixed around his trunk by Velcro straps. The elastic cords were applied in a spider shape. This suspension system "spider cage" provides horizontal and vertical dynamic features of functional suspension as a support, assistance, or even resistance during training. The suspension system also provides just the right amount of support needed for securing and balancing patient while practicing or performing needed movements [12]. Different types of exercises were applied according to the level of the cords.

(1) Cords beside: In which the level of the cords connected to the cage is at the same level of the cords connected to the belt so that the whole weight of the body falls on the lower limbs to give a chance for full weight bearing. At first, tension of cords was equal to each other. This enables the child to assume mid or upright position. Then the tension of cords was decreased gradually. The cords were checked to be elastic enough to allow the child to re-adjust himself and to develop his own control. The tension of the front and back cords were interchangeably decreased while repeating the same exercises. Different exercises were applied to improve balance from different positions including; high kneeling, half kneeling, kneel-walking, stoops and recover, standing weight shift, squatting from standing position (squat balance), kicking ball, throwing ball, stepping, jumping in place, jumping abroad, standing on one foot and standing on balance board.
(2) Full suspension: In this type the level of the cords connected to the cage was above the level of the cords connected to the belt in which the child was fully suspended (the child's feet were off the ground). This type of suspension was used as vestibular stimulation, to provide body awareness and to promote or develop postural reflexes (protective extension reactions, righting or equilibrium reactions).The therapist pulled the child backward, allowing him to swing forward and backward through space until he stops, also up and down, and side to side movements were allowed. Each child was asked to keep his balance, while he was moved through space. Duration of each exercise was 1–2 min with a time of rest (1–2 min) in between exercises [13].

The two groups in addition, received a designed exercises program for balance and posture control including the following items with clear instructions to the child to perform it:

(1) Standing with feet together while the therapist sitting behind and manually locking the child knees, and then slowly tilt him to each side, forward and backward.
(2) Step standing with therapist behind the child guiding him to shift his weight forward then backward alternately.
(3) High step standing and try to keep balanced.
(4) Standing with manual locking of the knees then tries actively to stoop and recover.
(5) Equilibrium, righting and protective reactions training.

Since gait is an important dynamic balance component so gait training was important for balance training. The following exercises were performed:

- Forward, backward, and sideways walking between the parallel bars (closed environment gait training).
- Obstacles including rolls and wedges with different diameters and heights, were put inside parallel bars.
- Open environment gait training was conducted with the previous obstacles but without parallel bars.

3. Results

The collected data from this study represent the statistical analysis of the stability indices including overall stability index, antero-posterior (A/P) stability index and medio-lateral (M/L) stability index of the dynamic balance test at the level 8 stability (more stable platform) were measured before and after three months of treatment for the two groups. The raw data of the measured variables for the two groups were statistically treated to determine the mean and standard deviation. Student t-test was then applied to examine the significance of the treatment conducted for each group. The obtained results in this study revealed no significant differences when comparing the pre-treatment mean values of the two groups. Significant improvement was observed in all the measuring variables of the two groups study I and study II, when comparing their pre and post-treatment mean values. After treatment significant difference was observed when comparing the post-treatment results of the two groups in favor of the study group II.

As revealed from table 1 and Fig. 1, significant reduction was observed in the mean values of stability indices for the study group I at the end of treatment as compared with the corresponding mean values before treatment.

Also, Table 2 and Fig. 2, showed a significant reduction in the mean values of stability indices for the study group II at the end of treatment as compared with the corresponding mean values before treatment.

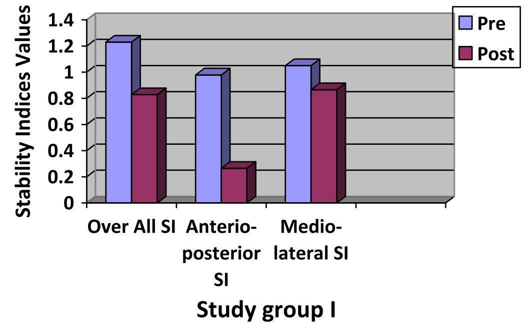

Figure 1 Demonstrating the pre and post-treatment mean values of the stability indices of the study group I.

Significant improvement was also observed when comparing the post-treatment mean values of the stability indices of the two groups in favor of the study group II ($P < 0.05$) as shown in Fig. 3.

4. Discussion

Impaired balance, gait disturbances and frequent falls are common problems in DS children. Down syndrome was found to demonstrate that deficits in postural control system that may provide a partial explanation for balance problems that are common in these subjects [14]. Recent meta-analysis found that abnormalities of gait or balance were the most consistent predictors of future falls [15].

Unruh [16] reported that children with DS have predominance of primitive, spinally controlled muscle responses patterns over more centrally integrated and coordinated movement patterns that is due to poor myelination of the descending cerebral and brain stem neurons and also reduction in both number and connection of the neurons in the higher nervous centers as motor cortex, basal ganglia, cerebellum and brain stem.

The purpose of this study was to compare between the effect of treadmill training and suspension therapy via using spider cage on balance in children with DS.

Conducting the study on children aged from 8 to 10 years may be attributed to the fact that, patients with DS between 7 and 14 years show defect in agility and balance tasks [17].

This also comes in agreement with Westcott et al. [18] who confirmed that infant and young children (aged 4 months to 2 years) are dependent to the visual system to maintain

Table 1 Pre and post-treatment mean values of the stability indices for the study group I.

	Stability indices					
	Over all SI		Antero-posterior SI		Medio-lateral SI	
	Pre	Post	Pre	Post	Pre	Post
X'	1.231	0.829	0.979	0.599	1.051	0.867
±SD	±0.158	±0.090	±0.266	±0.068	±0.108	±0.111
t-Test	2.696		2.501		8.215	
P-value	0 < 0.05		0 < 0.05		0 < 0.0001	
Sig.	Significant		Significant		Significant	

X': Mean; SD: Standard deviation; P-value: Level of Significance, Sig.: Significance; SI: Stability index.

Table 2 Pre and post-treatment mean values of the stability indices for the study group II.

	Stability indices					
	Over all SI		Antero-posterior SI		Medio-lateral SI	
	Pre	Post	Pre	Post	Pre	Post
X'	1.239	0.623	0.972	0.487	1.053	0.686
±SD	±0.149	±0.073	±0.256	±0.066	±0.092	±0.075
t-Test	2.147		2.283		2.658	
P-value	0 < 0.05		0 < 0.05		0 < 0.05	
Sig.	Significant		Significant		Significant	

X': Mean; SD: Standard deviation; *P*-value: Level of Significance, Sig.: Significance; SI: Stability index.

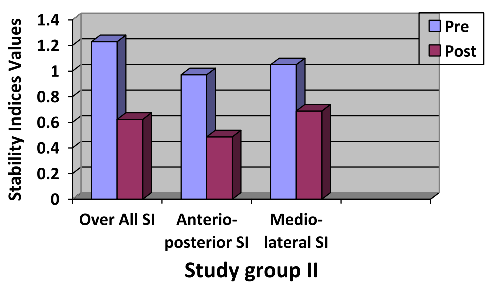

Figure 2 Illustrating the pre and post treatment mean values of the stability indices of the study group II.

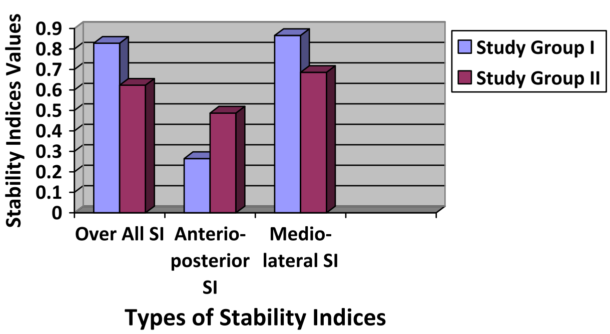

Figure 3 Representing the post-treatment mean values of the stability indices for the two groups (study group I and study group II).

balance, while at 3 to 6 years of age, children begin to use somatosensory information appropriately. Finally, at 7 to 10 years of age, children are able to resolve a sensory conflict and appropriately utilize the vestibular system as a reference. He added that, postural control is essentially adult like by about 7 to 10 years of age.

This age group was chosen as they had significant practice of their functional activities and changes in anthropometrics would have been fairly steady for several years [10].

The biodex stability system was used for evaluation using dynamic balance test which was performed on stability level 8. This agrees with Revel et al. [19] who reported that, balance assessment should attempt to stimulate dynamic condition in order to stress the postural control system fully and reveal the presence of balance disorder.

The pre-treatment mean values of overall stability index, anteroposterior stability index and mediolateral stability index of the dynamic balance test showed a significant increase in their values which indicated that those children had a significant balance problems.

The pre-treatment results of the present study were consistent with those reported by Testerman and Griend [20] who emphasized that the larger the numerical value of the stability index (represents the variance of platform displacement in degrees from level), the greater the degree of difficulty or instability in balancing the platform. This comes in agreement with Rozzi et al. [7] who concluded that, compared to low stability indices, high stability indices indicate greater platform motion during stance and therefore denoting less stability.

The post-treatment results of the study group I reinforced the effectiveness of treadmill training on improving balance by adopting suitable program of treadmill walking.

This agrees with Dingwell et al. [15] who recommended that the researches should be conducted to look at the long term effects of the treadmill training on the child's ability to negotiate obstacles in its pathway while maintaining the dynamic balance because the parents suggest that children with DS are more prone to fall when encountering obstacles in their environment.

This also comes in agreement with Carmeli et al. [21] who revealed the effects of a treadmill walking program on muscle strength and balance in elderly people with DS.

The improvement seen in the study group I may be due to stepping practice via treadmill training which strengthens and stabilizes the neural network involved in producing this pattern and improves the specific postural control mechanism needed to maintain the balance when transferring the weight from one leg to the other, so, treadmill as an example of stepping practice, facilitates and strengthens the neural connections that arise from the coupling of multimodal sensory input generated by the child through improving attention and awareness of the body position image in relation to his or her environment [22].

The post-treatment results of the study group I also come in agreement with Matsuno et al. [23] who concluded that the treadmill is considered as a moving surface, so, the children needed to spend more time with both feet on the surface during the walking cycle than when they walked over ground. Consequently, they spend less time with only one feet on the surface during treadmill walking than during over ground walking. He added that, one factor that contributes to improve stability and balance is the increase in the base of support.

Our results contradict those of Carmeli et al. [24] who assessed balance following ball exercises and treadmill training. There was a lack of improvement noted in both postural and balance control in those subjects as a result of 6 months of intervention.

In respect to the study group II who received suspension therapy via using spider cage, there was significant improvement in the mean values of stability indices.

This improvement in the study group II may be attributed to the use of spider cage. It provided more stabilization to the child which minimized the displacement of center of pressure (COP) under each foot, so keeping the COP near the middle. In addition to that, it helped the child to keep small amplitude of COP motion and decreased postural sway which reflected a good balance control and tended to achieve quiet stance [25].

Also, the post-treatment results of the study group II may be attributed to the effect of spider cage on improving the agonist/antagonist relationship of the lower limb muscles through loading and unloading (joints distraction and/or approximation) resulting in improvement of weight bearing activities through alteration of the proprioceptive sense. The results of this study come in agreement with Stillman [26] who reported that proprioceptive awareness of postures and movements is required during the learning of new skills. He added that, with slower movements the proprioceptive system can monitor and adjust the movements as they occur. This system is able to trigger immediate, rapid and precisely-tailored compensatory muscular contractions reflexively in response to unexpected changes in external or internal forces; for example as required during standing balance.

This confirms the findings of Keen [27] who reported that training with the use of spider cage helped the patient firstly to overcome the gravitational effect on their static and dynamic patterns and secondarily to modulate the muscle tone, which helped in keeping the body from collapsing.

It had been proved that there were abnormalities in the functioning of the vestibular apparatus of individuals with DS as the peripheral vestibular system including Scarpa's ganglion cells and vestibular hair cells, was affected [28,29].

Improvement observed in study group II may be due to the effect of suspension therapy which helped in the development of equilibrium reaction to maintain and regain balance during standing pattern. This can be achieved primarily from vestibular input and secondarily from proprioception and vision. If the speed or magnitude of displacement of the child's center of gravity is too great, vestibular, proprioception and vision (equilibrium reaction) will help to regain balance in such cases. This treatment gives postural stability while promoting independence with security which significantly improves balance, coordination of the body and the performance of the vestibule system [30].

Improvement fulfilled in the study groups I and II might be attributed to the effect of exercises therapy program for balance and postural control. This agrees with the findings of Carvalho and Almeida [31] who suggested that proprioceptive information is essential for the motor control system to select the appropriate motor strategy of reciprocal activation among the agonist and antagonist to efficiently maintain balance. Significant difference was observed when comparing the post-treatment results of the two groups in the favor of the study group II receiving suspension therapy via using spider cage. These results might be attributed to the effect of spider cage on improving function of the vestibular system. Stimulation of vestibular response provided by spider cage stimulates otolith organs through linear displacement. These findings come in agreement with Rine [32] who reported that stimulation of otolithic organs by transient linear acceleration and/or by changes in head position with respect to gravity evokes phasic and tonic vestibule–ocular and vestibule–spinal reflexes, which act on the head and limbs to maintain posture. He added that orientation in space depends to a high extent on input from vestibular receptors, visual cues, impulses from proprioceptors in joint capsules and from cutaneous extra receptors especially those of touch and pressure. These four inputs are integrated at various levels of the nervous system to maintain posture.

In conclusion, both treadmill training and suspension therapy via using spider cage are effective in treatment for Down syndrome children with high recommendation for using suspension therapy.

Acknowledgments

This work was supported in part by the Faculty of Physical Therapy, Cairo University. The critical comment offered on the initial draft of this manuscript by my colleagues at the department of Physical Therapy for the Growth and Developmental Disorder in Children and its Surgery are very much appreciated.

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